16

NOTE ON THE ZODIACAL LIGHT.

—BY—

HENRY CARVILL LEWIS.

[*From the* AMERICAN JOURNAL OF SCIENCE. *Vol. XX. December, 1880.*]

Digitized by the Internet Archive
in 2017 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/noteonzodiacalli00lewi_0

[From the American Journal of Science, Vol. XX, December, 1880.]

Art. XLVII.—*Note on the Zodiacal Light;* by Henry Carvill Lewis. With Plate VI.

[Read before the American Association for the Advancement of Science, Boston, August 28, 1880.]

It is designed in the present paper to make a brief record of the results obtained from observations of the zodiacal light extending over a period of nearly five years.* The facts here presented are deductions from a large number of closely accordant observations, the publication of which in detail must be reserved for some future opportunity.

The discordant results obtained by different observers have induced the writer to take special precautions in his method of observation. To map correctly such very faint objects, as those parts of the zodiacal light here called the zodiacal band and the gegenschein, requires absolute freedom from bias on the part of the observer. An atlas (Heis' Atlas Cœlestis), on which the ecliptic was not marked, was therefore used, and the gegenschein was plotted always without reference to the sun's longitude. Its angular distance from the sun was not calculated until after the close of the whole series of observations. In order to train the eye to more acute vision, it has been customary before each observation to use it in the detection of stars of the sixth magnitude and under.† It has been found that such practice is not only a good preparation for accurate observing, but that an idea of the comparative transparency of the atmosphere is thus obtained. In all cases the observations were made in perfect darkness, and recorded as soon after as possible.

---

* A short notice of the writer's work was published in the Annual Record of Science and Industry for 1878.

† The writer has frequently seen twelve stars in the Pleiades with his naked eye.

Nearly all of the observations were made in Germantown, Pa. (lat. 40°); but a few, especially those upon the "horizon light," were made at the sea-shore, on board ship, or on the mountains.

The zodiacal light may be divided into three portions:—the *Zodiacal Cone*, the *Zodiacal Band* and the *Gegenschein*. This division, in addition to its convenience, saves confusion in description, and may be, in part at least, a natural one.

The Zodiacal Cone.—This, the zodiacal light proper of most authors, and by far the most conspicuous of its three portions, has frequently been described and its outlines mapped. It is, however, often misrepresented in popular works on astronomy. It is the only part of the zodiacal light which varies in appearance. Its height above the horizon and its brightness are directly connected with the duration of twilight and the obliquity of the ecliptic. The most favorable time for viewing it is always immediately after the last trace of twilight has disappeared. It would be more frequently noticed, but that it is often confounded with twilight. While the last trace of twilight is a lateral expansion of light along the western horizon, the evening zodiacal cone, of about the same shade of color, rises obliquely as a cone which is more or less pointed according to the season. Its apex occasionally attains a distance of 100° from the sun.

In this latitude, the zodiacal cone is not a symmetrical figure, its southern side being more vertical than its northern side. Its southern side is also the more sharply defined of the two, and is the side more nearly parallel with the ecliptic. Its axis of greatest brightness does not correspond with its axis of symmetry, but lies south of it. There is a very small angle between these two axes. The axis of greatest brightness appears to lie precisely upon the ecliptic. The lateral extension of the base of the zodiacal cone, often observed, is probably a purely atmospheric effect.

The brightness of the zodiacal cone depends upon the season of the year and the time of the night when observed. Its brilliancy increases rapidly as it approaches the sun, and at such times as it can be seen nearest the sun it always appears brightest. The time of shortest twilight coincides with the greatest brilliancy of the zodiacal cone. In each of the five years the evening zodiacal cone was most brilliant from the middle of February to the middle of March. Several observations have proved it to cast a distinct *shadow* at that time.*

---

* Zodiacal light shadows were noticed on Feb. 12, 1877, at 7.15 P. M., and on Feb. 21, 1879, at 7.20 P. M. On the latter night snow covered the ground, on which distinct zodiacal light shadows were cast.

Numerous comparisons have been made between the brightness of the zodiacal cone and that of different parts of the Via Lactea, with the result that early in December of each year it becomes as bright as the Via Lactea, soon outshining it in brilliancy, until in April it again begins to become the fainter of the two objects. During July and August the cone, now lying on one side along the horizon, can only be seen from positions whence there is a very perfect horizon, and at that season has generally been confounded with twilight.

At the period of its maximum brightness an *inner cone* of much greater brilliancy can be detected near the horizon. This short inner cone is less pointed in shape than the outer one, although fading by degrees into it. It is many times brighter than the Via Lactea, and is slightly colored by atmospheric absorption. This inner cone appears directly above, and is suddenly obscured by the dark atmospheric *absorption band*, which is on the horizon.

Neither in this *inner cone* nor in the zodiacal cone in general has any color, except what can be explained by atmospheric absorption, been proved by the observations under discussion. Although a decidedly warm color has frequently been observed, it is found that this color, like that of the moon and planets at low altitudes, is variable, and depends upon atmospheric conditions. Comparison between the zodiacal cone and the last traces of twilight or the glow preceding moonrise, shows them to have a similar color when equally bright. The zodiacal cone in the morning is frequently more pale than that in the evening, for the same reason that sunrise has generally less deep colors than sunset.

Several observations indicate that the light of the zodiacal cone has a great penetrating power. Even under atmospheric conditions in which the Via Lactea is made nearly invisible, the zodiacal cone appears to lose but little of its light. The light is dense, though dull and ill-defined, and the impression is given that the matter producing it has great depth.

Careful watch has been made for any pulsations in the zodiacal cone. Although aware of the statements of some observers as to their existence, the writer, during the whole of his observations, has never once been able to detect any certain pulsations, any movement, or any sudden change in brightness in any part of the zodiacal light; and he believes that all such apparent effects are due either to atmospheric changes or to changes in the eyesight of the observer. Since frequently an apparent diminution in brightness ensues after the observer has been looking at another part of the sky, and especially after recording a note by lamplight, it has been found necessary to compare directly the brightness of the cone at a certain altitude with a definite portion of the Via Lactea; and it was then always noticed that the diminution in brightness of the zodiacal cone was accompanied by a corresponding change in the Via Lactea. Any change in the transparency of the atmosphere or in personal judgment affects equally both phenomena.

Not only have no pulsations been observed, but as yet no periodic variations in the appearance or brightness of the zodiacal cone have been noticed. The photometric observations were only approximate, but, so far as could be judged, the zodiacal cone each year went through the same series of changes; attaining each winter, at the time of its maximum brilliancy, an equal degree of brightness, and becoming equally faint each summer. The statements, which others have given of its remarkable brilliancy during the appearance of certain comets or other noticeable phenomena, may be accounted for on the hypothesis that at such times special attention is directed towards a certain class of celestial objects,—and a phenomenon generally ignored is thus brought to special notice. The observations of the writer tend to prove the invariability of the zodiacal light. The difference in its appearance is thought to be due merely to the different positions of the earth in reference to it.

Nor has the *moon* been discovered to have any action upon the appearance of the zodiacal cone. The zodiacal cone is frequently sufficiently bright to enable it to be seen when the moon is either in it or higher in the heavens. The presence of the moon does not appear to alter its shape. When the moon is above the zodiacal cone, but not on the ecliptic, it has been frequently observed that the axis of the cone points away from the moon, making with it a considerable angle. Again, the cone is found to preserve its shape, both while the moon lies within it, or on one side of it, or when, after having passed its first quarter, the moon illuminates it from above. The widening of the base of the zodiacal cone, as the moon lights up the horizon, is an atmospheric effect caused by the brightening of the "horizon light."

The writer has taken several observations upon the *spectrum* of the zodiacal cone. Three different spectroscopes, of different make,* have been used with accordant results. It was of interest to find that, notwithstanding the brilliancy of the cone when observed, nothing whatever could be seen when using a narrow slit,—a fact proving the truly continuous character of the spectrum. When a slit of over a millimeter in width was used, there appeared a faint, pale, continuous spectrum, brightest and most abruptly ending at the less refrangible end, and gradually fading at the other extremity. The slit was too wide to permit Fraunhofer lines to appear. The spectrum was of a pale greenish-gray color throughout, and was not unlike that given by late twilight. It was much shorter than that given by reflected moonlight. The peculiar ashy-gray color of this spectrum, which lies between the yellow and the green of the solar spectrum, and forms its most luminous portion, is probably characteristic of all very faint polychromatic lights. It is the last portion of the spectrum to disappear, and is nearer white than any other color. The spectroscopic observations of the writer agree with the more careful work of Smyth and Wright, and point to reflected sunlight as the source of the light of the zodiacal cone.

---

* Browning's one prism, Browning's direct vision, Eaton's direct vision,—the last being the most satisfactory.

The Zodiacal Band.—The zodiacal band is one of the faintest visible objects in the heavens, and has thus escaped the attention which it deserves. It may be described as an extremely faint zone of light, somewhat wider than the milky way, which, like a narrow strip of gauze, is stretched across the sky along the zodiac from horizon to horizon, and which can be seen at all times of the year and at all times of the night. It is a belt with parallel sides, of nearly equal width throughout, which, as though a second and much fainter milky way, forms a faint prolongation of the zodiacal cone across the sky. It is most favorably situated for observation at the same season of the year in which the zodiacal cone is best seen, when it forms a high and perfect arch from east to west. It is so faint that in order to detect it at any time it is necessary for the observer to seek out first the darkest places in the sky, shifting the eyes rapidly and continuously along the sky from north to south and the reverse, and thus by degrees to narrow the vision down to the faint band of light upon the zodiac. It is most easily seen late in the evening, after the zodiacal zone has sunk below the horizon; since the brightness of the latter is apt to dim it by contrast. It is also of course best seen when it makes a large angle with the Via Lactea, or when the latter is on the horizon.

The zodiacal band is brightest along an inner line, whence it fades off very gradually toward the edges. When most favorably situated, it seems to be more sharply defined on its southern than on its northern edge, and in this respect is similar to the zodiacal cone. Toward midnight the zodiacal band is decidedly brightest at the highest portion of the arch, where it contains the third division of the zodiacal light,—the gegenschein.

The width of the zodiacal band can only be very approximately estimated. As generally seen, it has perhaps a width of about 12°. When low down toward the southern horizon, this width is apparently greatly increased, and, the horizon light interfering, the whole southern sky beneath the Via Lactea may seem illuminated. On rare occasions it is possible to detect an inner zone of greater brightness, some 2° wide. At such times the principal band of light has a width of 5°–6°, while beyond and on either side a very diffuse portion measures from edge to edge as much as 20°. This diffuse portion is particularly noticeable on the northern edge. It must be understood that each of these portions shade by insensible degrees one into the other, and that probably no two observers would give the same widths.

The zodiacal band lies in the zodiac, upon or close to the ecliptic. The observations appear to show that while its axis of greatest brightness is either on or very slightly north of the ecliptic, the axis of symmetry is decidedly north of that line. Probably in the southern hemisphere the reverse would be the case.

The zodiacal band is generally quite obscured in the presence of the moon, but two or three observations are recorded, in which the zodiacal band has apparently been seen by moonlight. That such an extremely faint object as the zodiacal band should be seen by moonlight, as though illuminated by it, is an interesting fact, which, however, is not as yet sustained by sufficient observation.

The Gegenschein.—The term gegenschein, given by Brorsen to a light which appears opposite to the sun, but which has been confused by others with the eastern part of the zodiacal band, is here limited to the round or oval spot of light which nightly appears at that place in the zodiacal band which is 180° from the sun.

The writer has paid particular attention to the observation and careful mapping of this object. He has made more than forty maps of its position among the stars at different times, and upon subsequent calculation, he has found that almost without exception, the center of the gegenschein, thus mapped, lies within 1° or 2° of a point in the heavens 180° in longitude from the sun.

The gegenschein is an extremely faint spot of light some 7° in diameter, lying in the zodiacal band. It is best placed for observation about midnight, and can be detected by shifting the eye backward and forward along the zodiacal band. Anyone who looks for it in February and March, when the Via Lactea is low on the horizon, cannot fail to find it, first in Leo and afterwards in Virgo. Night after night it shifts its place among the stars, so as to keep opposite to the sun. It is of course invisible when crossing the Via Lactea.

The gegenschein is decidedly brighter than the zodiacal band, although always much fainter than any central portions of the Via Lactea. It often appears to form an oval whose major axis is parallel to the ecliptic. At such times its major axis may be 15° in length. This effect is probably caused by the brightness of the zodiacal band on either side of it, for careful observations show that the brighter portion is approximately circular.

Sometimes a *nucleus* of greater brightness has been noticed in the center of the gegenschein. This nucleus is a small definite circular spot of about 2° in diameter, and is only to be detected under favorable atmospheric conditions. Several maps have been made of the position of this nucleus. Generally the gegenschein appears as a nebulous patch of equally diffused light.

Perhaps the most interesting fact concerning the gegenschein which is clearly deduced from the maps of its position, is that it always lies some 2°± *north of the ecliptic.* While a number of observations place its center 3°—4° north of the ecliptic, not a single one makes it south of that line. This fact will be of importance in a theory of the gegenschein.

The extreme faintness of both the gegenschein and the zodiacal band made it impossible to obtain any spectrum other than that given by diffuse star-light.

Explanation of Plate.—Plate VI represents those observations of the gegenschein which were taken while it was near the vernal equinox. These observations, made at different times and upon different maps, are here for the first time plotted on one map and the line of the ecliptic added. The bounding lines of the different gegenscheins represent boundaries of more or less diffuse portions; and the various circular figures on the plate are not to be regarded as showing difference in size and shape of the gegenschein. They are merely indices to locality.

The dates of observations were as follows:—

1. Feb. 4, 1880.
2. Feb. 4, 1878.
3. Feb. 7, 1880.
4. Feb. 9, 1877.
5. Feb. 14, 1879.
6. Feb. 21, 1879.
7. Mar. 5, 1880.
8. Mar. 5, 1877.
9. Mar. 9, 1877.
10. Mar. 15, 1877.
11. Mar. 25, 1879.
12. Mar. 31, 1880.
13. Apr. 5, 1877.
19. Apr. 5, 1880.
14. Apr. 6, 1877.
15. Apr. 6, 1878.
16. Apr. 7, 1880.
17. Apr. 10, 1877.
18. Apr. 14, 1877.

The Moon Zodiacal Light.—A phenomenon is described under this head by Rev. George Jones,* in his interesting series of observations upon the zodiacal light, as a short, oblique cone about in the plane of the ecliptic, seen in the immediate proximity of the moon. He observed it several times just before moonrise. It may have been owing to an inferior horizon, but, although careful search was made, at no time has the present writer been able to detect any such appearance. The light which precedes the rising of the moon is found uniformly to rise at right angles to the horizon. This light spreads out laterally along the horizon, and appears to be a purely atmospheric effect.

---

* U. S. Japan Exped., iii, 329, et seq.

Another kind of "moon zodiacal light" is described in a recent paper with the above title in the Proceedings of the American Acad. of Arts and Sciences.* Here the observer describes comet-like tails extending on each side of the moon to a distance of 8–10 times its diameter. The sky was soon after overcast with dense vapors, and after all such vapors had disappeared, these appearances also vanished. They were supposed to have a connection with both the zodiacal light and the aurora.

Similar appearances have been observed by the present writer only upon similarly cloudy evenings, at which time diffraction caused by floating vapor might have explained what was seen. Since such phenomena have not been seen on clear evenings, it is thought that these effects are probably purely atmospheric.

The writer has not, as yet, been able to recognize in his observations any direct connection between the zodiacal light and the moon.

The aurora appears to have no influence whatever upon any portion of the zodiacal band.

The Horizon Light.—More than once in this paper, reference has been made to a light which it has been found convenient to designate by the above name. It has no connection whatever with the zodiacal light; but since it is continually observed with that phenomenon, and at certain seasons of the year blends with and is apt to be confounded with portions of it, it is necessary to take it into account. Unlike the zodiacal light, it is a terrestrial effect.

The horizon light is a faint band of white light with parallel sides, lying all around and parallel to the horizon, and separated from it by an interval of darkness. It is seen on every clear night and at all times of the night. This band of light is most bright and terminates most abruptly on its lower edge. Its upper edge fades off very gradually into the sky. Its comparatively sharp lower edge is at an altitude of some 5° above the horizon. The diffuse upper edge varies in altitude with the state of the atmosphere. On clear nights it has probably a mean altitude of $20° \pm$, the horizon light being therefore some 15° broad. The clearer the night the narrower is the horizon light. On hazy nights it reaches far up toward the zenith. At such times it is possible that artificial earth-lights aid in its extension. The horizon light disappears when the sky is overcast.

Its brightness is variable. At times its lower portion seems as bright as the Via Lactea and at other times is fainter than the gegenschein. When the moon is in the sky it becomes exceedingly bright and wide, far surpassing the Via Lactea. Just before the time of the rising of the moon it widens out on both the east and west horizons. Stars are readily seen through the horizon light and are but slightly dimmed in luster. The horizon light can most easily be detected by inclining the head toward the shoulder and glancing from the zenith to the horizon.

---

* Proc. Amer. Acad. Arts and Sc., Nov., 1877, p. 183.

The horizon light appears to be caused by reflected starlight. That diffuse skylight is sufficiently bright may be proved by noting its power to cast a shadow.

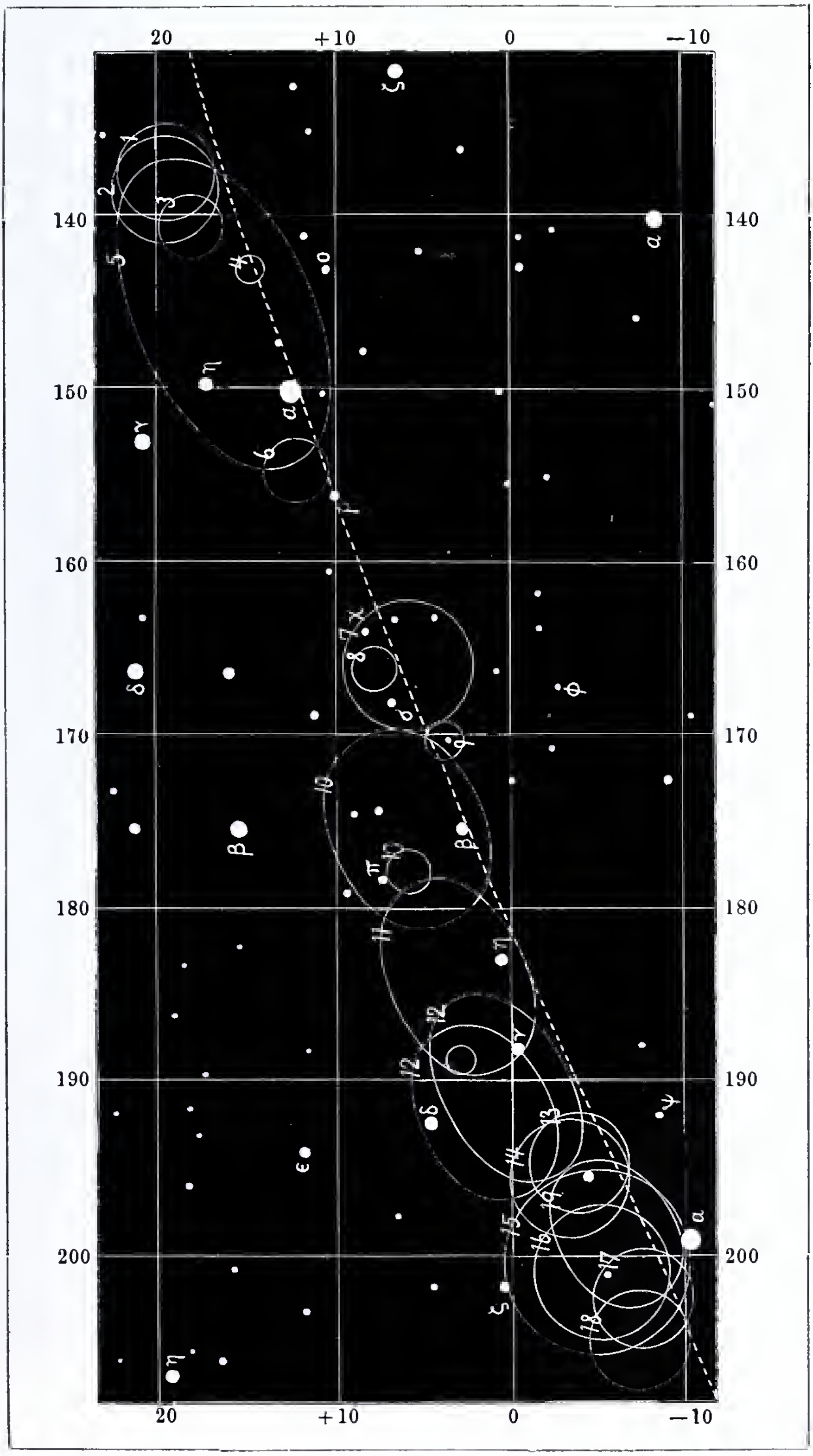
Below the horizon light and resting upon the horizon is a dark space which we may designate the *Absorption Band.* It is darker than the sky at the zenith, and quenches all faint celestial lights. The Via Lactea ends abruptly at its upper portion and the zodiacal cone, even when very bright, extends only slightly into it. Their comparative brightness may be estimated by noting how low down they penetrate the absorption band. No stars can be seen through its lower portion and rarely through its upper part, at such times being deeply colored. The moon and the larger planets are colored red while in it. The absorption band is some 5° broad, and is of course only seen when the observer has a perfect horizon.

In the study of the zodiacal light it is important that both the horizon light and the absorption band should be recognized. In the summer, when the ecliptic is low, and the zodiacal band lies far down toward the southern horizon, the horizon light frequently blends with it, greatly interfering with its determination. The two illuminate the southern sky, and it is difficult if not impossible at times to separate one from the other.

Conclusion.—Other observers have contributed much of importance concerning the phenomena of the zodiacal light, and several theories of its origin have been proposed. No theory is advanced in the present paper, and, as the observations are being continued, these partial results alone are presented as a contribution to the store of facts already collected on this interesting phenomenon.

Germantown, Pa., August, 1880.

Plate VI.


20
+10
0
—10
140
150
160
170
180
190
200
ζ
α
η
γ
δ
β
ε
ψ
φ
π
χ
ρ
ο
σ
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18